US009572220B2

(12) United States Patent
Kim et al.

(10) Patent No.: US 9,572,220 B2
(45) Date of Patent: Feb. 14, 2017

(54) **LED LIGHTING APPARATUS AND CONTROL CIRCUIT THEREOF**

(71) Applicant: **SILICON WORKS CO., LTD.**, Daejeon (KR)

(72) Inventors: **Yong Goo Kim**, Daejeon-si (KR); **Won Ji Lee**, Cheonahn-si (KR); **Kyung Min Kim**, Daejeon-si (KR); **Jong Min Lee**, Busan (KR); **Min Soo Kim**, Chungcheongbuk-do (KR); **Young Suk Son**, Daejeon (KR)

(73) Assignee: **SILICON WORKS CO., LTD.**, Daejeon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/901,544**

(22) PCT Filed: **Jun. 25, 2014**

(86) PCT No.: **PCT/KR2014/005628**
§ 371 (c)(1),
(2) Date: **Dec. 28, 2015**

(87) PCT Pub. No.: **WO2014/209009**
PCT Pub. Date: **Dec. 31, 2014**

(65) **Prior Publication Data**

US 2016/0143107 A1 May 19, 2016

(30) **Foreign Application Priority Data**

Jun. 28, 2013 (KR) 10-2013-0075422

(51) **Int. Cl.**
H05B 33/08 (2006.01)

(52) **U.S. Cl.**
CPC ***H05B 33/0851*** (2013.01); ***H05B 33/0824*** (2013.01); ***H05B 33/0887*** (2013.01)

(58) **Field of Classification Search**
CPC H05B 33/0815; H05B 33/0818; H05B 33/0884; H05B 33/0809; H05B 33/0848; H05B 33/0896
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,593,232 A * 6/1986 McEdwards H05B 39/09 315/199
2002/0140373 A1* 10/2002 Ribarich H05B 41/2855 315/224

(Continued)

FOREIGN PATENT DOCUMENTS

KR 10-2011-0051062 5/2011
KR 10-2012-0008004 1/2012
KR 10-2013-0013221 2/2013

OTHER PUBLICATIONS

International Search Report for International Application No. PCT/KR2014/005628, dated Oct. 21, 2014.

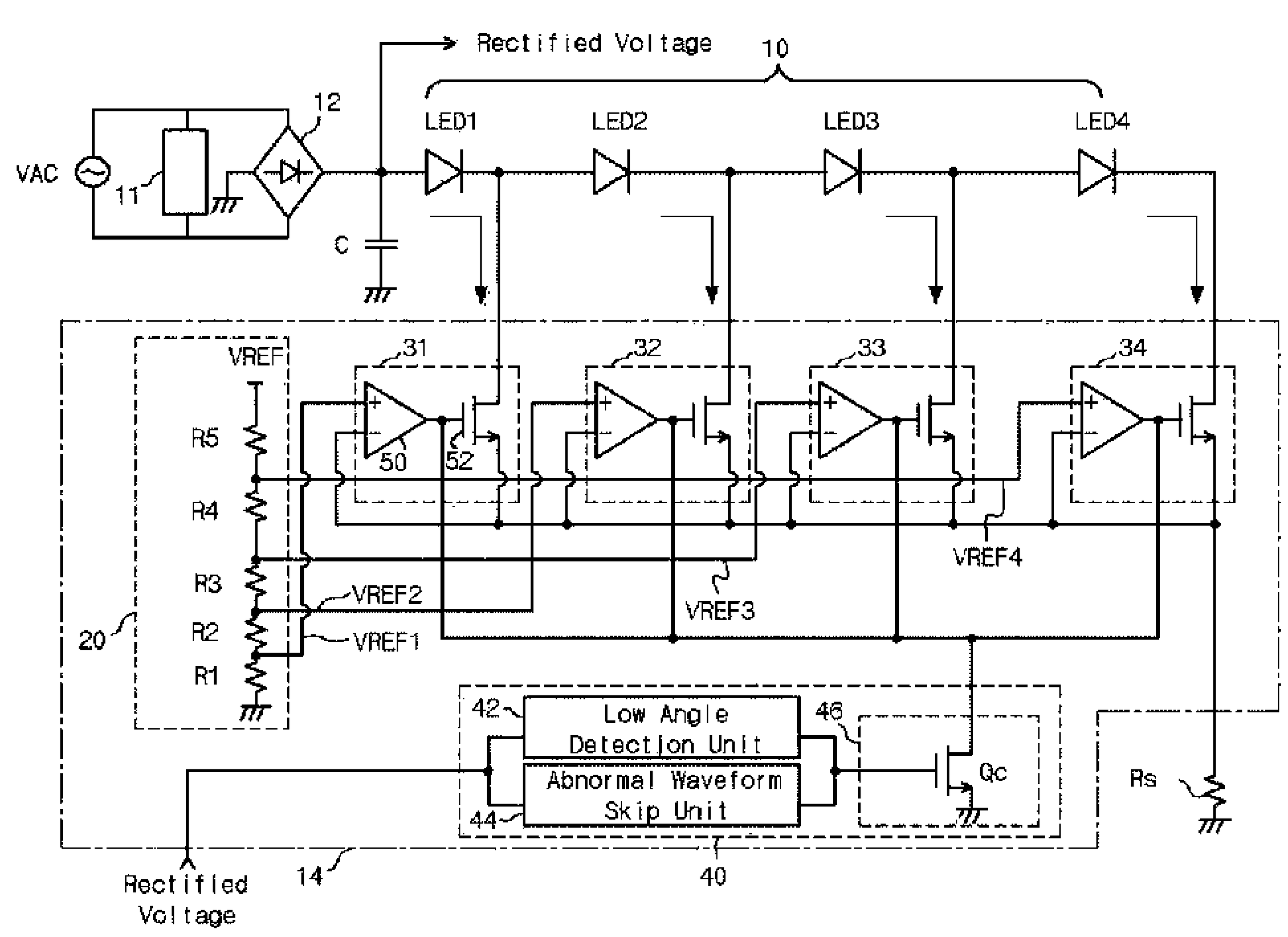
(Continued)

Primary Examiner — Douglas W Owens
Assistant Examiner — Syed M Kaiser
(74) *Attorney, Agent, or Firm* — Kile Park Reed & Houtteman PLLC

(57) **ABSTRACT**

Disclosed are an LED lighting apparatus and a control circuit thereof which controls illumination of a lamp including LEDs using a dimmer. The LED lighting apparatus includes a flicker control unit which provides a control signal corresponding to a rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level or detects an initial abnormal waveform diagram of the rectified voltage and provides a control signal corresponding to the abnormal waveform period, and controls a current path for light emission of the lamp.

14 Claims, 4 Drawing Sheets



(58) **Field of Classification Search**
USPC 315/246, 294, 297, 307, 224, 121
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

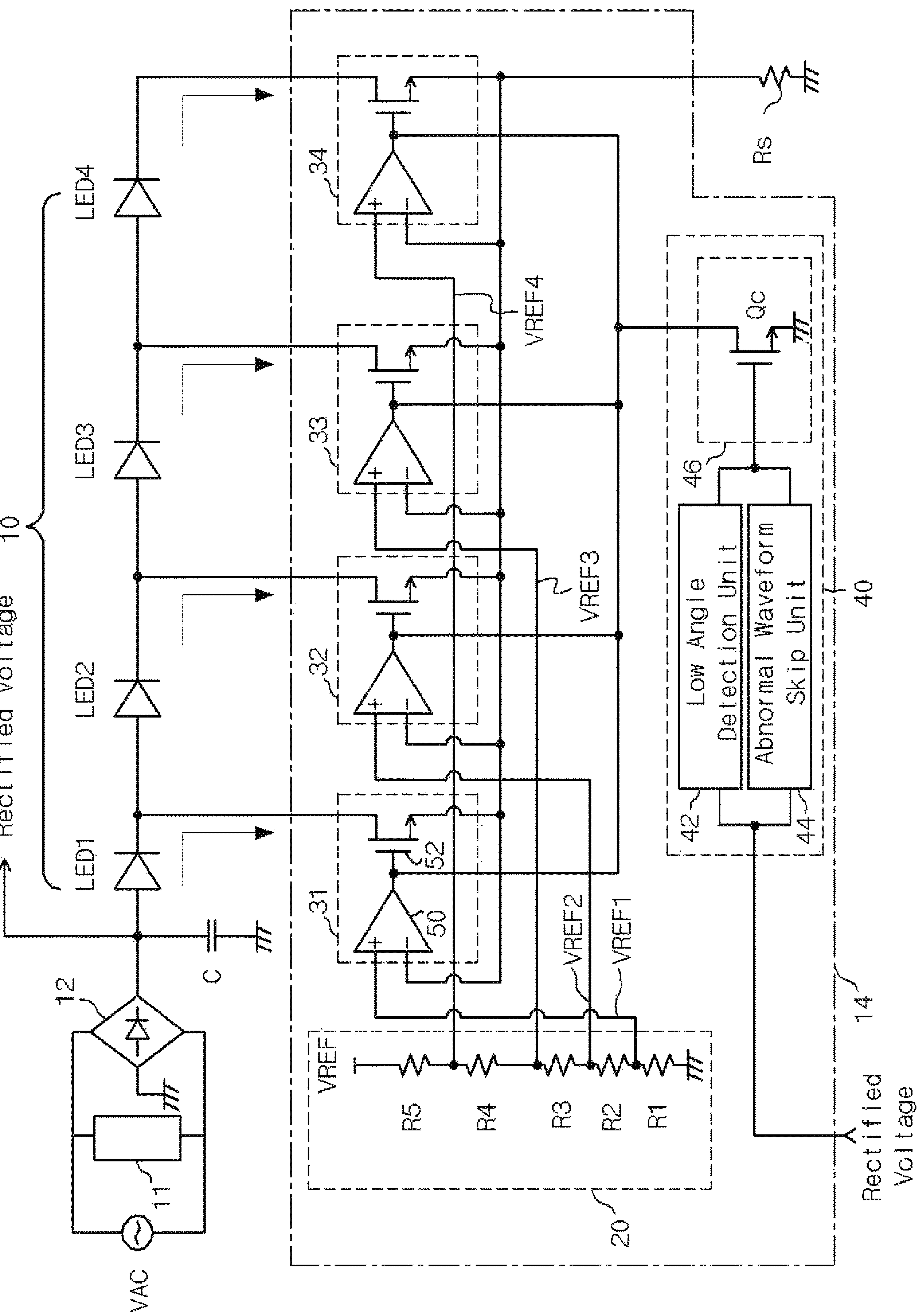
2011/0227489	A1	9/2011	Huynh	
2012/0013265	A1	1/2012	Yang et al.	
2012/0319604	A1*	12/2012	Walters	H02M 3/1582 315/200 R
2014/0361695	A1*	12/2014	Akiyama	H05B 33/0812 315/185 R
2015/0163873	A1*	6/2015	Kawai	H05B 33/0815 315/127

OTHER PUBLICATIONS

Written Opinion for International Application No. PCT/KR2014/005628, dated Oct. 21, 2014.

* cited by examiner

FIG. 1



Rectified Voltage
10
LED1
LED2
LED3
LED4
12
11
VAC
C
31
32
33
34
50
52
VREF4
VREF3
VREF2
VREF1
VREF
R5
R4
R3
R2
R1
20
Rs
Qc
46
Low Angle Detection Unit
Abnormal Waveform Skip Unit
42
44
40
14
Rectified Voltage

FIG. 2

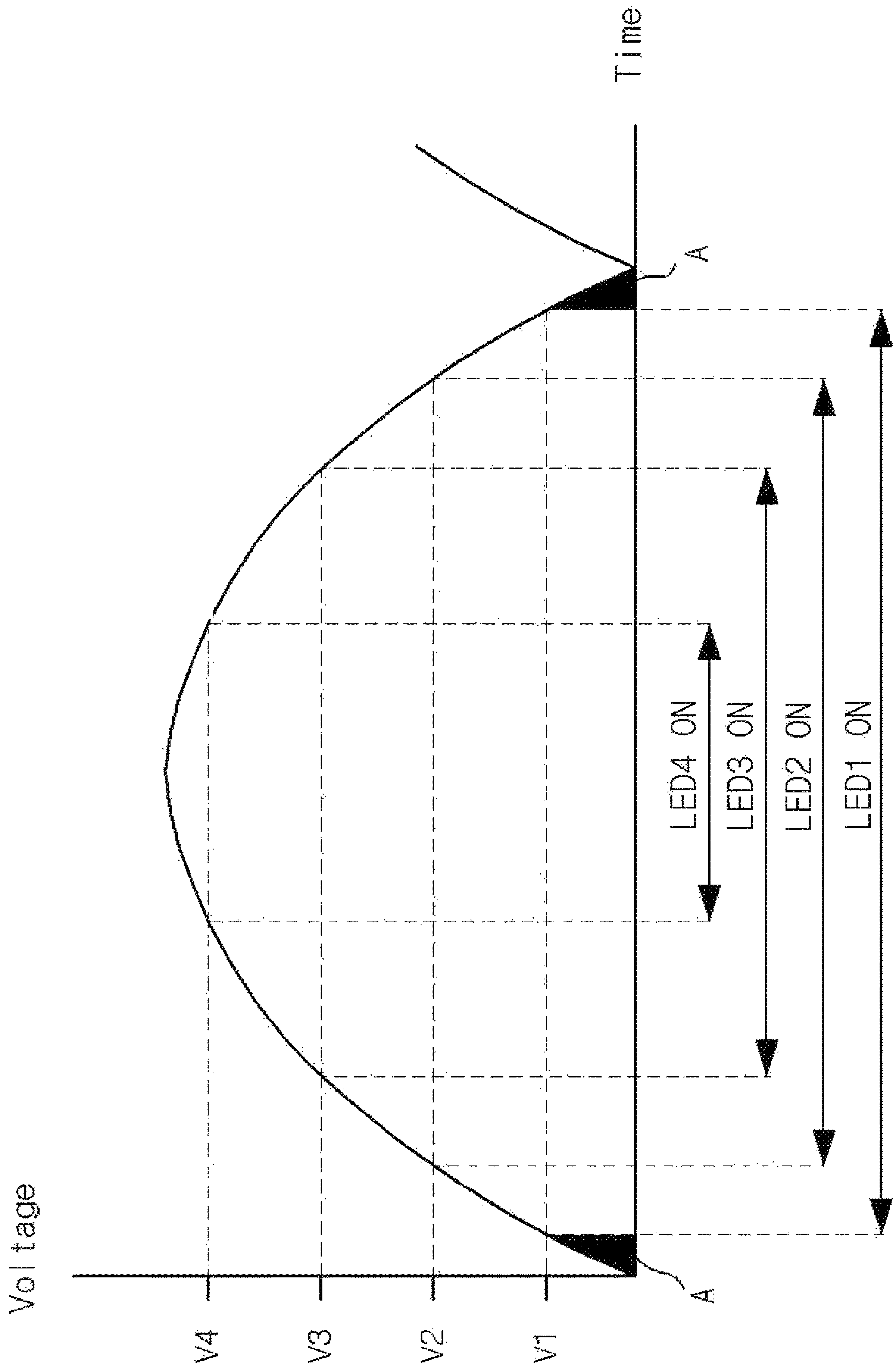


FIG. 3

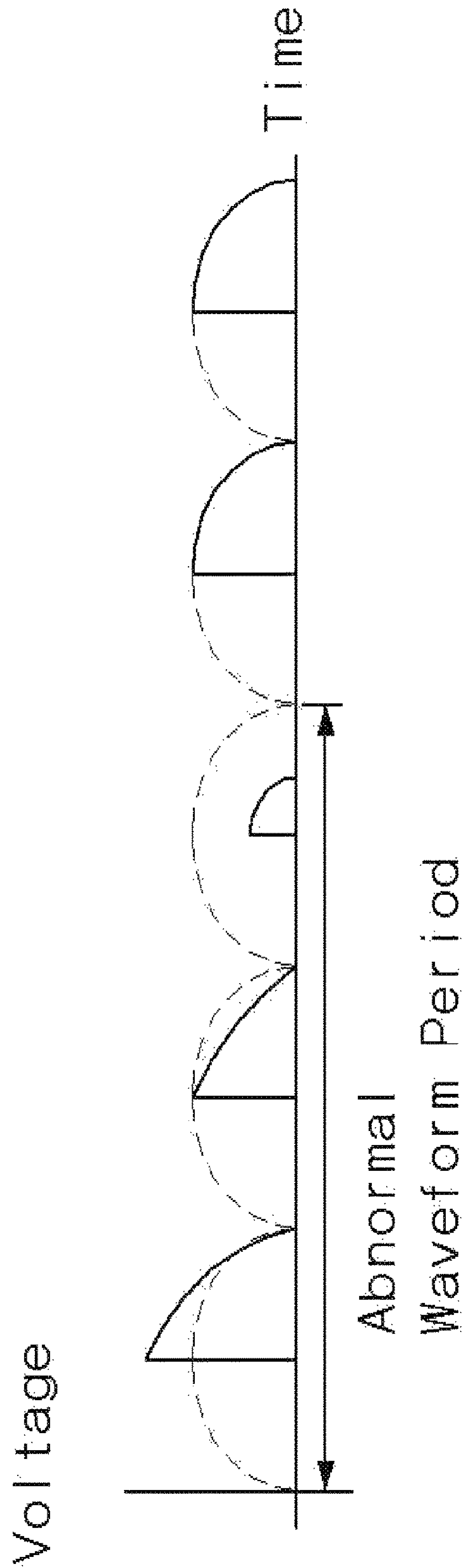
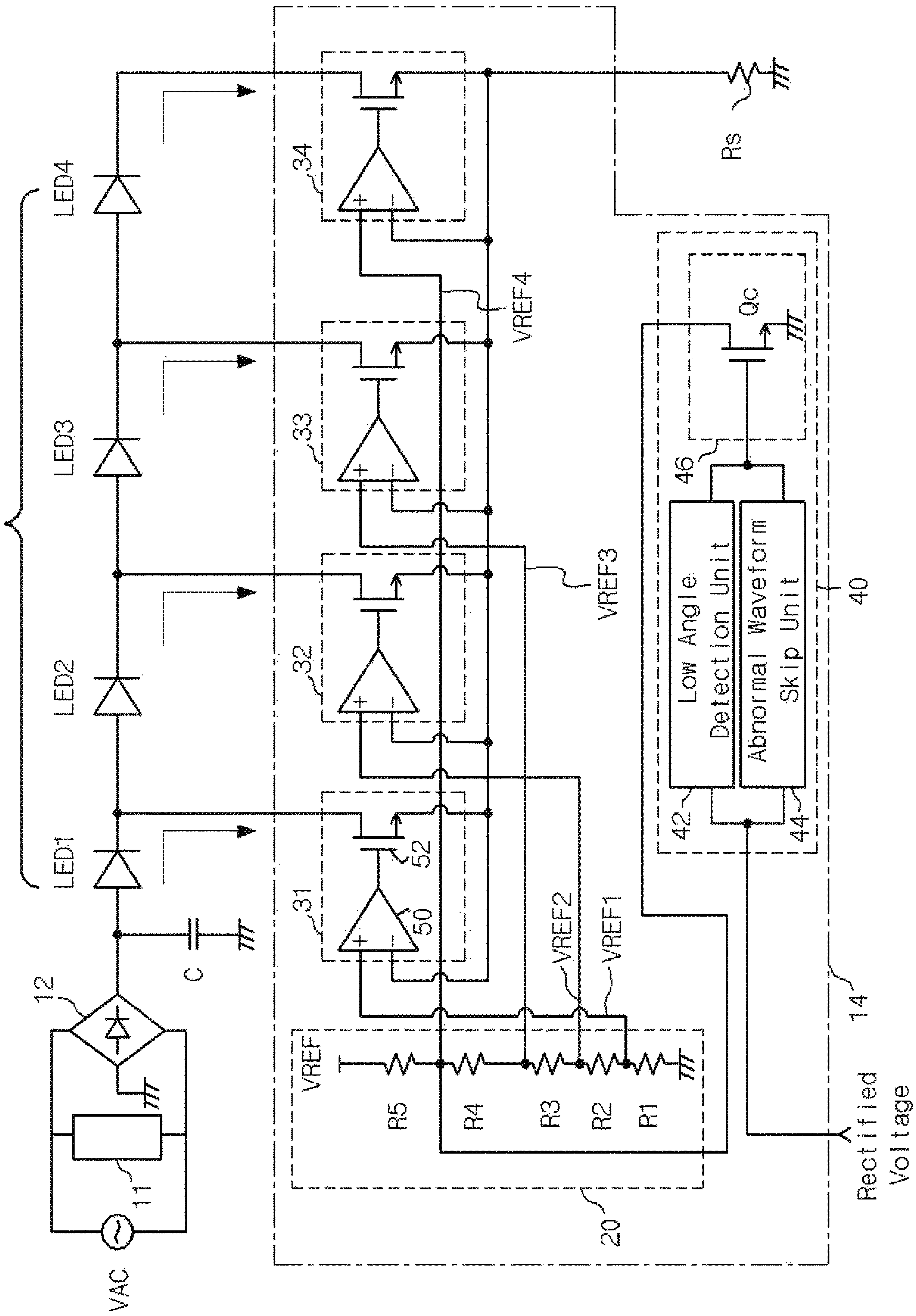


FIG. 4



10
LED1
LED2
LED3
LED4
VAC
11
12
C
31
32
33
34
50
52
VREF
VREF1
VREF2
VREF3
VREF4
R1
R2
R3
R4
R5
20
Rs
Qc
46
Low Angle Detection Unit
Abnormal Waveform Skip Unit
42
44
40
14
Rectified Voltage

LED LIGHTING APPARATUS AND CONTROL CIRCUIT THEREOF

TECHNICAL FIELD

The present disclosure relates to an LED lighting apparatus, and more particularly, to an LED lighting apparatus and a control circuit thereof which controls illumination of a lamp including LEDs using a dimmer.

BACKGROUND ART

According to the recent trend of lighting technology, an LED has been employed as a light source, in order to reduce energy.

A high-brightness LED is differentiated from other light sources in terms of various aspects such as energy consumption, lifetime, and light quality.

However, since the LED is driven by a current, a lighting apparatus using the LED as a light source requires a large number of additional circuits for current driving.

In order to solve the above-described problem, an AC direct-type lighting apparatus has been developed.

The AC direct-type LED lighting apparatus generates a rectified voltage using a commercial AC power supply and drives an LED. Since the AC direct-type LED lighting apparatus directly uses the rectified voltage as an input voltage without using an inductor and capacitor, the AC direct-type LED lighting apparatus has a satisfactory power factor.

A general LED lighting apparatus is designed to be driven through a voltage obtained by rectifying commercial power having an AC voltage.

A lamp of the LED lighting apparatus includes a large number of LEDs connected in series to each other, and controls the LEDs connected in series to emit light using the rectified voltage.

Recently, the LED lighting apparatus has employed a dimmer using a triac, in order to control brightness. The dimmer is generally used to control the brightness of an incandescent lamp.

When the dimmer is applied to the LED lighting apparatus, there may occur a difference between a design value of the LED lighting apparatus and the characteristic of the triac used as a part of the dimmer.

The triac of the dimmer has a holding current which may be changed in response to the characteristic difference. Thus, when a low-angle rectified voltage is provided to the LED lighting apparatus employing the dimmer including the triac, an insufficient level thereof may cause a flicker.

Furthermore, according to the characteristic and use environment of the triac included in the dimmer, a rectified voltage having an abnormal waveform may be inputted to the lamp at the initial stage.

When the rectified voltage having an abnormal waveform is inputted to the lamp, a flicker may occur in the initial state where the LED lighting apparatus is driven.

The conventional LED lighting apparatus must reduce the occurrence of the flicker, in order to perform the brightness control function using the dimmer including the triac.

DISCLOSURE

Technical Problem

Various embodiments are directed to an LED lighting apparatus and a control circuit thereof which employs a

dimmer using a triac to perform a brightness control function and is capable of reducing flicker which occurs in a low angle region of a rectified voltage.

Also, various embodiments are directed to an LED lighting apparatus and a control circuit thereof which employs a dimmer using a triac to perform a brightness control function and is capable of reducing flicker by skipping an initial abnormal waveform of a rectified voltage.

Technical Solution

In an embodiment, there is provided a control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac. The control circuit may include: a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups; a flicker control unit configured to provide a control signal in response to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level; and a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the control signal.

In another embodiment, there is provided a control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac. The control circuit may include: a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups; a flicker control unit configured to detect an initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period; and a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path during the abnormal waveform period in response to the control signal.

In another embodiment, there is provided a control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac. The control circuit may include: a flicker control unit configured to provide a control signal corresponding to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level or detect an initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period; a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups, and vary the output levels of the reference voltages in response to the control signal; and a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the level changes of the reference voltages by the control signal.

In another embodiment, an LED lighting apparatus may include: a lamp including a plurality of LEDs divided into a plurality of LED groups which sequentially emit light; a power supply unit including a triac and configured to provide a rectified voltage to the lamp using an AC voltage having a phase controlled through the triac; a control circuit configured to selectively provide a current path in response to light emission of the LED groups, provide the current path by comparing reference voltages supplied at different levels to the respective groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level or detect an initial abnormal waveform period of the rectified voltage and turn off the current path in response to the abnormal waveform period; and a current sensing element configured to provide the current sensing voltage for the current path.

Advantageous Effects

In accordance with the embodiments of the present invention, the LED lighting apparatus and the control circuit can perform the brightness control function through the dimmer using the triac and reduce flicker occurring in the low angle region of the rectified voltage or flicker caused by an initial abnormal waveform of the rectified voltage. The LED lighting apparatus can be stably driven.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a circuit diagram illustrating an LED lighting apparatus and a control circuit thereof in accordance with an embodiment of the present invention.

FIG. **2** is a waveform diagram for describing the operation of the embodiment of FIG. **1**.

FIG. **3** is a diagram for describing a method of skipping an abnormal waveform.

FIG. **4** is a circuit diagram illustrating a modification of FIG. **1**.

MODE FOR INVENTION

Hereafter, embodiments of the present invention will be described in detail with reference to the accompanying drawings. The terms used in the present specification and claims are not limited to typical dictionary definitions, but must be interpreted into meanings and concepts which coincide with the technical idea of the present invention.

Embodiments described in the present specification and configurations illustrated in the drawings are preferred embodiments of the present invention, and do not represent the entire technical idea of the present invention. Thus, various equivalents and modifications capable of replacing the embodiments and configurations may be provided at the point of time that the present application is filed.

The embodiments of the present invention disclose a technology for controlling the brightness of a lamp **10** including LEDs by applying a dimmer using a triac to a power supply unit. In the embodiments of the present invention, the dimmer is implemented with a triac **11**, but the present invention is not limited thereto.

Referring to FIG. **1**, an LED lighting apparatus in accordance with an embodiment of the present invention includes a lamp **10**, a power supply unit including a triac **11**, and a control circuit. The control circuit has a function of detecting a low-level rectified voltage in a low-angle region or reducing flicker by skipping an abnormal waveform of the rectified voltage at the initial stage, while selectively providing current path for light emission of the lamp **10**.

The lamp **10** includes LEDs divided into a plurality of LED groups. As described below with reference to FIG. **2**, the LED groups of the lamp **10** are sequentially turned on or off according to a ripple of the rectified voltage supplied from the power supply unit.

FIG. **1** illustrates that the lamp **10** includes four LED groups LED**1** to LED**4**. Each of the LED diode groups LED**1** to LED**4** may include a plurality of LEDs connected in series, parallel, or serial-parallel to each other. For convenience of description, the plurality of LEDs are represented by one diode symbol.

The power supply unit is configured to rectify an AC voltage introduced from outside and output the rectified voltage.

The power supply unit may include an AC power supply VAC for supplying an AC voltage, the triac **11**, a rectifier circuit **12** for outputting the rectified voltage, and a capacitor C for smoothing the rectified voltage outputted from the rectifier circuit **12**. The AC power supply VAC may include a commercial power supply.

The triac **11** has a dimming function of controlling the brightness of the lamp **10**. The triac **11** may control the phase of the AC voltage transmitted to the rectifier circuit **12** according to control of a user using a control unit (not illustrated) which is separately included in the dimmer, and the brightness of the lamp **10** may be adjusted through the phase control of the AC voltage by the triac **11**.

The phase control of the AC voltage by the triac **11** may be performed by controlling conduction timing based on the position at which the zero potential of the sine-wave AC voltage is detected (zero potential detection position). That is, the triac **11** may output an AC voltage to have a phase controlled according to the conduction timing.

The rectifier circuit **12** full-wave rectifies the AC voltage having a waveform of which the phase is controlled by the triac **11**, and outputs the rectified voltage. Thus, as illustrated in FIG. **2**, the rectified voltage has a ripple at which the voltage level thereof is repetitively changed on a basis of a half cycle of the AC voltage.

The control unit includes a control unit **14** and a current sensing resistor Rs. The control unit **14** performs current regulation for light emission of the respective LED groups LED**1** to LED**4**, and provides a current path through the current sensing resistor Rs of which one end is grounded.

According to the above-described configuration, the LED groups LED**1** to LED**4** of the lamp **10** are sequentially turned on or off in response to rises or falls of the rectified voltage, and the control unit **14** performs current regulation to selectively provide a current path for light emission of the respective LED groups LED**1** to LED**4**.

The light emission voltage V**4** is defined as a voltage for controlling all of the LED groups LED**1** to LED**4** to emit light, the light emission voltage V**3** is defined as a voltage for controlling the LED groups LED**1** to LED**3** to emit light, the light emission voltage V**2** is defined as a voltage for controlling the LED groups LED**1** and LED**2** to emit light, and the light emission voltage V**1** is defined as a voltage for controlling only the LED group LED**1** to emit light.

The control unit **14** may provide a current path by performing current regulation using the current sensing voltage of the current sensing resistor Rs, and the current sensing voltage may be varied by the current amount of the current path, which is changed according to the light emitting states of the respective LED groups of the lamp **10**. At this time, the current flowing through the current sensing resistor Rs may include a constant current.

The control unit **14** includes a plurality of switching circuits **31** to **34** and a reference voltage supply unit **20**. The plurality of switching circuits **31** to **34** provide a current path for the LED groups LED**1** to LED**4**, and the reference voltage supply unit **20** provides reference voltages VREF**1** to VREF**4**.

The reference voltage supply unit **20** includes a plurality of resistors R**1** to R**5** which are connected in series to receive a constant voltage VREF. The resistor R**1** is connected to a ground, and the resistor R**5** receives the constant voltage VREF and serves as a load resistor for adjusting an output. The resistors R**1** to R**4** serve to output the reference voltages VREF**1** to VREF**4** having different levels. Among the reference voltages VREF**1** to VREF**4**, the reference voltage VREF**1** may have the lowest voltage level, and the reference voltage VREF**4** may have the highest voltage level.

The resistors R**1** to R**4** may have resistance values which are set to output four reference voltages VREF**1** to VREF**4** of which the levels gradually rise in response to variations of the rectified voltage applied to the LED groups LED**1** to LDE**4**.

The reference voltage VREF**1** has a level for turning off the switching circuit **31** at the point of time that the LED group LED**2** emits light. More specifically, the reference voltage VREF**1** may be set to a level equal to or lower than the current sensing voltage which is formed in the current sensing resistor Rs by the light emission voltage V**2**.

The reference voltage VREF**2** has a level for turning off the switching circuit **32** at the point of time that the LED group LED**3** emits light. More specifically, the reference voltage VREF**2** may be set to a level equal to or lower than the current sensing voltage which is formed in the current sensing resistor Rs by the light emission voltage V**3**.

The reference voltage VREF**3** has a level for turning off the switching circuit **33** at the point of time that the LED group LED**4** emits light. More specifically, the reference voltage VREF**3** may be set to a level equal to or lower than the current sensing voltage which is formed in the current sensing resistor Rs by the light emission voltage V**4**.

The reference voltage VREF**4** may be set to a higher level than the current sensing voltage which is formed in the current sensing resistor Rs by the upper limit level of the rectified voltage.

The switching circuits **31** to **34** are commonly connected to the current sensing resistor Rs for providing the current sensing voltage.

The switching circuits **31** to **34** are turned on or off according to comparison results between the current sensing voltage of the current sensing resistor Rs to the reference voltages VREF**1** to VREF**4** of the reference voltage supply unit **20**, and selectively provide a current path corresponding to the light emitting state of the lamp **10**.

Each of the switching circuits **31** to **34** receives a high-level reference voltage as the switching circuit is connected to an LED group away from the position to which the rectified voltage is applied. Each of the switching circuits **31** to **34** may include a comparator **50** and a switching element, and the switching element may include an NMOS transistor **52**.

The comparator **50** included in each of the switching circuits **31** to **34** receives the reference voltage through a positive input terminal (+) thereof, receives the current sensing voltage through a negative input terminal (−) thereof, and outputs the comparison result between the reference voltage and the current sensing voltage through an output terminal thereof.

According to the above-described configuration, the embodiment of FIG. **1** controls the lamp **10** to emit light and performs a current regulation operation for light emission of the lamp **10**. This operation will be described with reference to FIG. **2**.

When the rectified voltage is in the initial state, the plurality of LED groups LED**1** to LED**4** do not emit light. Thus, the current sensing resistor Rs may provide a low-level current sensing voltage.

In this case, all of the switching circuits **31** to **34** maintain the turn-on state, because the reference voltages VREF**1** to VREF**4** applied to the positive input terminals (+) of the respective switching circuits **31** to **34** are higher than the current sensing voltage applied to the negative input terminals (−).

Then, when the rectified voltage rises to reach the light emission voltage V**1**, the LED group LED**1** of the lamp **10** emits light. When the LED group LED**1** of the lamp **10** emits light, the turned-on switching circuit **31** of the control unit **14**, connected to the LED group LED**1**, provides a current path.

When the rectified voltage reaches the light emission voltage V**1** such that the LED group LED**1** emits light, the current path is formed through the switching circuit **31**, and the level of the current sensing voltage Vsense of the current sensing resistor Rs rises. At this time, however, since the level of the current sensing voltage is low, the turn-on states of the switching circuits **31** to **34** are not changed.

Then, when the rectified voltage continuously rises to reach the light emission voltage V**2**, the LED group LED**2** of the lamp **10** emits light. When the LED group LED**2** of the lamp **10** emits light, the turned-on switching circuit **32** of the control unit **14**, connected to the LED group LED**2**, provides a current path. At this time, the LED group LED**1** also maintains the light emitting state.

When the rectified voltage reaches the light emission voltage V**2** such that the LED group LED**2** emits light, the current path is formed through the switching circuit **32**, and the level of the current sensing voltage Vsense of the current sensing resistor Rs rises. At this time, the current sensing voltage has a higher level than the reference voltage VREF**1**. Therefore, the NMOS transistor **52** of the switching circuit **31** is turned off by an output of the comparator **50**. That is, the switching circuit **31** is turned off, and the turned-on switching circuit **32** provides a current path corresponding to the light emission of the LED group LED**2**.

Then, when the rectified voltage continuously rises to reach the light emission voltage V**3**, the LED group LED**3** of the lamp **10** emits light. When the LED group LED**3** of the lamp **10** emits light, the turned-on switching circuit **33** of the control unit **14**, connected to the LED group LED**3**, provides a current path. At this time, the LED groups LED**1** and LED**2** also maintain the light emitting state.

When the rectified voltage reaches the light emission voltage V**3** such that the LED group LED**3** emits light, the current path is formed through the switching circuit **33**, and the level of the current sensing voltage of the current sensing resistor Rs rises. At this time, the current sensing voltage has a higher level than the reference voltage VREF**2**. Therefore, the NMOS transistor **52** of the switching circuit **32** is turned off by an output of the comparator **50**. That is, the switching circuit **32** is turned off, and the turned-on switching circuit **33** provides a current path corresponding to the turn-on of the LED group LED**3**.

Then, when the rectified voltage continuously rises to reach the light emission voltage V**4**, the LED group LED**4** of the lamp **10** emits light. When the LED group LED**4** of the lamp **10** emits light, the turned-on switching circuit **34** of the control unit **14**, connected to the LED group LED**4**, provides a current path. At this time, the LED groups LED**1** to LED**3** also maintain the light emitting state.

When the rectified voltage reaches the light emission voltage V**4** such that the LED group LED**4** emits light, the current path is formed through the switching circuit **34**, and the level of the current sensing voltage of the current sensing resistor Rs rises. At this time, the current sensing voltage has a higher level than the reference voltage VREF**3**. Therefore, the NMOS transistor **52** of the switching circuit **33** is turned off by an output of the comparator **50**. That is, the switching circuit **33** is turned off, and the turned-on switching circuit **34** provides a selective current path corresponding to the light emission of the LED group LED**4**.

Then, although the rectified voltage continuously rises, the switching circuit **34** maintains the turn-on state, because the reference voltage VREF**4** provided to the switching circuit **34** has a higher level than the current sensing voltage formed in the current sensing resistor Rs by the upper limit level of the rectified voltage.

The rectified voltage starts to falls after the upper limit level. When the rectified voltage falls below the light emission voltage V4, the LED group LED**4** of the lamp **10** is turned off. When the LED group LED**4** of the lamp **10** is turned off, the LED groups LED**3**, LED**2**, and LED**1** maintain the light emitting state, and the control unit **14** provides a current path through the switching circuit **33** in response to the light emitting state of the LED group LED**3**.

Then, when the rectified voltage sequentially falls below the light emission voltages V**3**, V**2**, and V**1**, the LED groups LED**3**, LED**2**, and LED**1** of the lamp **10** are sequentially turned off. As the LED groups LED**3**, LED**2**, and LED**1** of the lamp **10** are sequentially turned off, the control unit **14** provides a selective current path in order of the switching circuits **33**, **32**, and **31**.

The embodiment of FIG. **1** may include a flicker control unit **40**, and the flicker control unit **40** includes a low angle detection unit **42**, an abnormal waveform skip unit **44**, and a driving unit **46**.

The low angle detection unit **42** receives the rectified voltage supplied to the lamp **10**, and outputs a low angle detection signal in order to prevent the occurrence of flicker at a low angle because a holding current is changed by a characteristic difference of the triac **11**.

More specifically, the low angle detection unit **42** scales down the rectified voltage, determines whether the scaled-down rectified voltage is equal to or less than a preset voltage, and outputs the determination result as the low angle detection signal. Due to the characteristic difference by the triac **11**, the holding current be changed, and a rectified voltage having a low angle may be supplied to the lamp **10**, while having a level equal to or less than a permissible level. In this case, the lamp **10** may flicker due to the low-level rectified voltage. When a rectified voltage having a low angle and being equal to or less than a predetermined voltage is detected, the low angle detection unit **42** outputs a low angle detection signal for preventing flickering of the lamp **10**.

That is, as illustrated in FIG. **2**, the low angle detection unit **42** may set a region A in which the LED group LED**1** is turned off to a low angle region, and detect that a rectified voltage having a low angle corresponding to the low angle region and being equal to or less than the preset level is provided to the lamp **10**.

The abnormal waveform skip unit **44** receives the rectified voltage supplied to the lamp **10**, and outputs an abnormal waveform skip signal in response to an abnormal waveform period of the rectified voltage at the initial stage as illustrated in FIG. **3**.

The abnormal waveform skip unit **44** may set a predetermined period of time to the abnormal waveform period, based on the point of time that the rectified voltage starts to be applied as illustrated in FIG. **3**. Then, while counting a cycle, the abnormal waveform skip unit **44** may output an abnormal waveform skip signal during a preset cycle.

The initial rectified waveform may be abnormally provided to the lamp **10** during a predetermined time, due to the characteristic of the triac **11**. Thus, the abnormal waveform skip unit **44** may output an abnormal waveform skip signal during a predetermined cycle, that is, during the period in which the abnormal waveform is detected.

The driving unit **46** may include a switching element which is driven by the low angle detection signal of the low angle detection unit **42** and the abnormal waveform skip signal of the abnormal waveform skip unit **44**. The switching element may include an NMOS transistor Qc.

The driving unit **46** may be commonly connected to the gates of the switching elements included in the respective switching circuits **31** to **34**, that is, the NMOS transistors **52**.

The control unit **14** including the flicker control unit **40** configured in the above-described manner performs a control operation for a low angle and abnormal waveform of the rectified voltage, while performing current regulation in response to sequential turn-on/off of the respective LED groups of the lamp **10**. Furthermore, the control unit **14** outputs a control signal for the control operation. The control signal may be defined as a signal applied by the NMOS transistor Qc of the driving unit **46**.

The low angle detection unit **42** detects whether the rectified voltage having an angle controlled by the triac **11** has a level equal to or less than a preset voltage while having a low angle corresponding to the low angle region such as the region A of FIG. **2**.

That is, the low angle detection unit **42** determines whether the rectified voltage has a low angle corresponding to the low angle region such as the region A of FIG. **1** and has a voltage level equal to or less than the preset voltage, in a state where the rectified voltage is scaled down. When the rectified voltage corresponds to a low angle and has a level equal to or less than the preset voltage, the low angle detection unit **42** outputs a low angle detection signal. For example, the low angle detection unit **42** may detect the light emission voltage V**1** or the rectified voltage having a low angle equal to or less than a level which is slightly higher than the light emission voltage V**1**, and output a low angle detection signal in an enable state (for example, high level). The level which is slightly higher than the light emission voltage V**1** may be set to a level at which flicker is likely to occur, and determined through an experiment.

When the low angle detection unit **42** is configured to detect a rectified voltage equal to or less than the light emission voltage V**1**, the low angle detection unit **42** outputs the low angle detection signal corresponding to the rectified voltage at a high level, the rectified voltage corresponding to the low angle region and being equal to or less than the light emission voltage V**1**.

The NMOS transistor Qc of the driving unit **46** maintains the turn-off state as the low-level low angle detection signal is applied in the initial normal state.

When the rectified voltage is equal to or less than the preset voltage and corresponds to the low angle region, the low angle detection unit **42** outputs the low angle detection signal at a high level, and the NMOS transistor Qc of the driving unit **46** is turned on. As the NMOS transistor Qc is turned on, the gate potentials of the NMOS transistors **52** of the switching circuits **31** to **34** is dropped to a low level.

Thus, when the rectified voltage equal to or less than the preset voltage level and having a low angle is inputted to the lamp **10** due to the characteristic of the triac **11**, the lamp **10** maintains the turn-off state in response to the turn-off of the NMOS transistors **52** of the switching circuits **31** to **34**. That is, according to the control of the driving unit **46** using the low angle detection signal, the turn-off state of the NMOS transistor **52** can be stabilized. As a result, an unstable situation or flicker caused by the characteristic of the dimmer **11** can be prevented.

Furthermore, when the rectified voltage starts to be applied as illustrated in FIG. **3**, the abnormal waveform skip unit **44** outputs an abnormal waveform skip signal during a preset cycle based on the point of time that the rectified voltage is applied. That is, the abnormal waveform skip unit **44** outputs the abnormal waveform skip signal at a high level during the preset cycle from the point of time that the rectified voltage is applied.

The NMOS transistor Qc of the driving unit **46** maintains the turn-off state in response to the abnormal waveform skip signal which is provided at a low level in a normal state.

However, when the abnormal waveform skip unit **44** outputs the abnormal waveform skip signal at a high level, the NMOS transistor Qc of the driving unit **46** is turned on. As the NMOS transistor Qc is turned on, the gate potentials of the NMOS transistors **52** of the switching circuits **31** to **34** are dropped to a low level.

Thus, the abnormal waveform skip signal maintains a high level during the cycle in which the abnormal waveform is applied at the initial stage of the rectified voltage due to the characteristic of the triac **11**, and the NMOS transistors of the switching circuits **31** to **34** maintain the turn-off state in response to the high-level abnormal waveform skip signal. That is, according to the control of the driving unit **46** using the abnormal waveform skip signal, light emission of the lamp **10** by the rectified voltage having an unstable waveform at the initial stage can be skipped.

As a result, it is possible to prevent the occurrence of flicker in the lamp **10** by the rectified voltage having an unstable waveform at the initial stage due to the triac **11**.

FIG. **1** illustrates that the driving unit **46** is commonly connected to the switching circuits **31** to **34**. However, the present invention is not limited thereto, but a plurality of driving units **46** may correspond one-to-one to the respective switching circuits **31** to **34**. At this time, the low angle detection signal of the low angle detection unit **42** and the abnormal waveform skip signal of the abnormal waveform skip unit **44** may be commonly provided by the plurality of driving units **46**.

Furthermore, as illustrated in FIG. **4**, the present embodiment may control the light emission of the lamp **10** by adjusting the reference voltages of the reference voltage supply unit **20**, unlike the configuration FIG. **1**. As a result, the occurrence of flick may be reduced.

In the embodiment of FIG. **4**, the same parts as those of FIG. **1** are represented by like reference numerals, and the duplicated descriptions thereof are omitted herein.

In the embodiment of FIG. **4**, the driving unit **46** is connected to a node between the resistors R**5** and R**4** of the reference voltage supply unit **20**.

That is, the NMOS transistor Qc of the driving unit **46** has a source connected to the node which outputs the reference voltage having the highest level among the nodes of the resistors included in the reference voltage supply unit **20**.

According to the above-described configuration, the driving unit **46** is turned on when the low angle detection signal of the low angle detection unit **42** and the abnormal waveform skip signal of the abnormal waveform skip unit **44** are applied at a high level.

The level of the node between the resistors R**5** and R**4** of the reference voltage supply unit **20** falls to the ground voltage when the NMOS transistor Qc of the driving unit **46** is turned on, and rises to the reference voltage VREF**4** when the NMOS transistor Qc of the driving unit **46** is turned off. Furthermore, the voltages of the nodes from which the other reference voltages VREF**1**, VREF**2**, and VREF**3** are outputted also swing between the ground voltage and the respective reference voltages in connection with the operation of the driving unit **46**.

When the NMOS transistor Qc of the driving unit **46** is turned on in response to the period in which the low angle detection signal and the abnormal waveform skip signal are applied at a high level, all of the levels of the reference voltages VREF**1** to VREF**4** fall to the ground voltage. In this case, each of the comparators **50** outputs a low-level voltage to the gate of the transistor **52**. In connection with the operations of the comparators **50**, the gate voltages of the NMOS transistors **52** included in the switching circuits **31** to **34** are turned off, and the current path is blocked.

When the NMOS transistor Qc of the driving unit **46** is turned off in response to a normal period in which the low angle detection signal and the abnormal waveform skip signal are applied at a low level, the levels of the reference voltages VREF**1** to VREF**4** are recovered. Thus, the comparators of the switching circuits **31** to **34** perform a normal operation according to the level of the rectified voltage.

Thus, while the low angle detection signal and the abnormal waveform skip signal are outputted at a high level due to the characteristic of the triac **11**, the NMOS transistors **52** of the switching circuits **31** to **34** stably maintain the turn-off state. As a result, an unstable situation or flicker of the lamp **10** caused by the characteristic of the triac **11** or environment factors can be prevented.

As such, the embodiment of FIG. **4** can also prevent an unstable situation or flicker of the lamp **10** caused by the characteristic of the triac **11** or environment factors, like the embodiment of FIG. **1**.

Therefore, the LED lighting apparatus and the control circuit thereof in accordance with the embodiment of the present invention may employ the dimmer using the triac to perform the bright control function, and reduce flicker occurring in a low angle region of the rectified voltage or flicker caused by an abnormal waveform of the rectified voltage at the initial stage, thereby stably driving the LED lighting apparatus.

While various embodiments have been described above, it will be understood to those skilled in the art that the embodiments described are by way of example only. Accordingly, the disclosure described herein should not be limited based on the described embodiments.

The invention claimed is:

1. A control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac, the control circuit comprising:

a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups;

a flicker control unit configured to provide a control signal in response to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level; and

a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the control signal,

wherein the control circuit controls flicker caused by a change of the rectified voltage which occurs due to the triac.

2. The control circuit of claim **1**, wherein the flicker control unit comprises:

a low angle detection unit configured to output a low angle detection signal in response to the rectified voltage having the low angle corresponding to the preset low angle region and equal to or less than the preset level; and

a driving unit configured to output the control signal corresponding to the low angle detection signal.

3. A control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac, the control circuit comprising:

a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups;

a flicker control unit configured to detect an initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period; and

a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path during the abnormal waveform period in response to the control signal,

wherein the control circuit controls flicker caused by a change of the rectified voltage which occurs due to the triac.

4. The control circuit of claim **3**, wherein the flicker control unit further provides the control signal in response to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level.

5. The control circuit of claim **4**, wherein the flicker control unit comprises:

a low angle detection unit configured to output a low angle detection signal in response to the rectified voltage having the low angle corresponding to the preset low angle region and equal to or less than the preset level;

an abnormal waveform skip unit configured to detect the initial abnormal waveform period of the rectified voltage and provide an abnormal waveform skip signal corresponding to the abnormal waveform period; and

a driving unit configured to output the control signal corresponding to the low angle detection signal and the abnormal waveform skip signal.

6. The control circuit of claim **3**, wherein the flicker control unit comprises:

an abnormal waveform skip unit configured to detect the initial abnormal waveform period of the rectified voltage and provide an abnormal waveform skip signal corresponding to the abnormal waveform period; and

a driving unit configured to output the control signal corresponding to the abnormal waveform skip signal.

7. The control circuit of claim **1**, wherein the flicker control unit provides the control signal to switching elements included in the respective switching circuits, and turns off the current path.

8. The control circuit of claim **7**, wherein each of the switching circuits comprises:

a comparator configured to compare the reference voltage to the current sensing voltage and output the comparison result; and

a switching element configured to selectively provide the current path according to the control signal and the output of the comparator.

9. A control circuit of an LED lighting apparatus, which controls a lamp divided into a plurality of LED groups to emit light in response to a rectified voltage outputted through a dimmer using a triac, the control circuit comprising:

a flicker control unit configured to provide a control signal corresponding to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level or detect an initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period;

a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups, and vary the output levels of the reference voltages in response to the control signal; and

a plurality of switching circuits configured to selectively provide a current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the level changes of the reference voltages by the control signal.

10. The control circuit of claim **9**, wherein the reference voltage supply unit comprises a plurality of resistors connected in series, nodes for the respective resistors output the reference voltages having different levels to the respective LED groups, and the control signal is applied to the node which outputs the reference voltage having the highest level.

11. An LED lighting apparatus comprising:

a lamp comprising a plurality of LEDs divided into a plurality of LED groups which sequentially emit light;

a power supply unit comprising a triac and configured to provide a rectified voltage to the lamp using an AC voltage having a phase controlled through the triac;

a control circuit configured to selectively provide a current path in response to light emission of the LED groups, provide the current path by comparing reference voltages supplied at different levels to the respective groups to a current sensing voltage corresponding to the current amount of the current path, and turn off the current path in response to the rectified voltage having a low angle corresponding to a preset low angle region and equal to or less than a preset level or detect an initial abnormal waveform period of the rectified voltage and turn off the current path in response to the abnormal waveform period; and

a current sensing element configured to provide the current sensing voltage for the current path.

12. The LED lighting apparatus of claim **11**, wherein the control circuit comprises:

a reference voltage supply unit configured to provide reference voltages having different levels to the respective LED groups;

a flicker control unit configured to a control signal corresponding to the rectified voltage having the low angle corresponding to the preset low angle region and equal to or less than the preset level or detect the initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period; and

a plurality of switching circuits configured to selectively provide the current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to the current sensing voltage, and turn off the current path during the abnormal waveform period in response to the control signal.

13. The LED lighting apparatus of claim **11**, wherein the control circuit comprises:

a flicker control unit configured to provide a control signal corresponding to the rectified voltage having the low angle corresponding to the preset low angle region and equal to or less than the preset level or detect the initial abnormal waveform period of the rectified voltage and provide a control signal corresponding to the abnormal waveform period;

a reference voltage supply unit configured to provide the reference voltages having different levels to the respective LED groups, and vary the output levels of the reference voltages in response to the control signal; and

a plurality of switching circuits configured to selectively provide the current path in response to light emission of the LED groups, perform current regulation for selectively providing the current path by comparing the reference voltages of the respective LED groups to the current sensing voltage, and turn off the current path in response to the level changes of the reference voltage by the control signal.

14. The control circuit of claim **3**, wherein the flicker control unit provides the control signal to switching elements included in the respective switching circuits, and turns off the current path.

* * * * *